J. Appl. Ent. 124, 169–176 (2000)

ISSN 0931-2048

Possible storage of *Coccinella undecimpunctata* (Col., Coccinellidae) under low temperature and its effect on some biological characteristics

A. H. Abdel-Salam and N. F. Abdel-Baky
Economic Entomology Department, Faculty of Agriculture, Mansoura University, El-Mansoura, Egypt

Abstract: Developmental stages of *Coccinella undecimpunctata* L. were stored at 6.0°C for various storage periods in a refrigerator. Egg hatching was 65.0% after 7 days of storage. However, no egg hatching were observed after 15, 30, 45 and 60 days of storage. The survival of the third and fourth instar larvae was higher than the first and second instar. The survival of larvae declined sharply after 15 days. No larvae survived after 30 or 60 days of storage. Emergence percentage of adults from stored pupae varied from 85.0 to 25.0% after storage for 7 up to 30 days. The survival percentage of adults differed and appeared to depend on prior feeding before storage. From the present results, it appears that the adult stage may be better able to survive extended periods of storage than the other developmental stages. In addition, it was found that prior feeding of adult stage affected the longevity, fecundity and consumption rate.

1 Introduction

Coccinella undecimpunctata L. is one of the most important predators encountered in Egyptian fields. It is being considered as a potential agent for biological control of aphids, cotton leafworm, whiteflies and other soft-bodied insects (Ibrahim, 1955; Ghanim and El-Adl, 1987a; Darwish and Ali, 1991). Detailed studies of the biology, life history, feeding capacity, prey preference of its larval and adult stages, seasonal abundance, effect of insecticides, its enemies and assessment of its role against several insect pests have been studied extensively (Ibrahim, 1955; Hafez et al., 1977; Hamed et al., 1979, 1983; El-Heneidy et al., 1979; Hassanein and Hamed, 1983; Hamed and Hassanein, 1984; Ghanim and El-Adl, 1987b, 1987c; Fayad and Ibrahim, 1988; Ali et al., 1989; El-Heneidy and Attia, 1991; El-Ghareeb, 1992; Eraky and Nasser, 1993; Kayapinar and Kornosor, 1993; El-Maghraby et al., 1994; Abdel-Salam, 1995).

Storage ability of predators for long-term (more than 2 weeks) may be a key factor in the successful development of mass rearing and augmented methods of biological control (Osman and Selman, 1993). Cold storage of predator insects benefits biological control efforts by using an alternative method of shipping to farmers for sale; reserving sufficient numbers of predators for field release at the optimal time, and if insectary colonies fail, providing flexibility in mass production and making standardized stock for use in long-term biological, ecological and physiological research (Hofsvang and Hagvar, 1977; Tauber et al., 1993).

The possibility of cold storage has been studied for many coccinellids. Shands and Simpson (1972) stored *Coccinella septempunctata* L. eggs at 10°C. The adults of *Adonia variegata* (Goeze) and *C. septempunctata* have been stored in the laboratory at 5°C (Borodkin, 1973). Quezada and Debach (1973) held *Rodalia cardinalis* Mul. pupae and adults at 55°F (12.5°C). Eggs of *C. septempunctata* and *Adalia bipunctata* L. were stored for 1 or 2 weeks at 10°C (Hamalainen and Markkula (1977) and Hamalainen (1977) stored adults of the previous species at 6°C. *Harmonia axyridis* Pallas adults have been stored at 5°C (Deng, 1982) and Abdel-Salam et al. (1997) stored *H. axyridis* adults at 4, 8 and 12°C for 15, 30, 45 and 60 days.

No previous studies have been carried out concerning the effect of low temperature on the coccinellid predator, *C. undecimpunctata*. Therefore, this study was carried out to investigate the effect of low temperature on hatchability, survival, emergence, longevity, fecundity and consumption rate of *C. undecimpunctata*.

2 Materials and methods

The parental stocks of *C. undecimpunctata* were collected from pea fields at the Experimental Research Station, Faculty of Agriculture, Mansoura University. The adults were maintained on *Aphis craccivora* Koch. in an air-conditioned insectary at 28.0 ± 2.0°C, 75.0 ± 5% relative humidity and photoperiod of 14 h light : 10 h dark for egg laying and the eggs were removed daily. Individual egg masses were placed in a glass Petri dishes (9 cm diameter) and monitored daily for hatching. Larvae were reared on *A. craccivora* individually in Petri dishes to avoid cannibalism. A piece of filter paper was placed on the bottom of the dish to facilitate larval movement and absorb the humidity. Aphids were added in excess to the dish. Additional aphids were added daily as the larvae grew. The dates of each instar of larvae, pupae and adult eclosion were recorded.

To determine the best stage for storage, various immature stages (eggs, first, second, third, fourth instar of larvae and

U. S. Copyright Clearance Center Code Statement: 0931–2048/2000/2403–0169 $ 15.00/0

Table 1. *Hatching, survival or emergence percentage of* C. undecimpunctata *stages stored at 6°C for different periods of storage*

Storage periods (days)	No.	Hatching of eggs (%)	Survival percentage of larval instars				Adults emergence from stored pupae (%)	Survival percentage of adults after		
			1st	2nd	3rd	4th		emergence	5 days	10 days
7	20	65.0	50.0	85.0	90.0	100.0	85.0	25.0	100.0	100.0
15	20	0	0	10.0	15.0	15.0	65.0	15.0	80.0	75.0
30	20	0	0	0	0	0	25.0	10.0	70.0	60.0
45	20	0	0	0	0	0	0	0	50.0	50.0
60	20	0	0	0	0	0	0	0	15.0	35.0

pupae) of the predator were placed in Petri dishes. Adults were divided into three groups, the first one after eclosion directly without feeding, the second after 5 days and the last group after 10 days from emergence with feeding on aphids. All of the various developmental stages were held in a refrigerator at 6.0°C and 60.0% relative humidity (constant darkness) for 7, 15, 30, 45 and 60 days. There were 20 replicates for each developmental stage and storage period. After the storage period was complete, all developmental stages were transferred individually to an air-conditioned insectary at 28.0 ± 2.0, 75.0 ± 5% relative humidity and photoperiod of 14 h light : 10 h dark.

The hatching percentage of eggs, percentage of survival of each larval instar and adult emergence from stored pupae were determined. In respect of adults, survival percentage, longevity, fecundity and consumption rate were recorded. For comparison, control (unstored) adult stage were also reared and maintained in similar conditions.

Data on longevity, fecundity and consumption rate of adults were analysed with one way analysis of variance with storage periods and days after emergence as factors. Comparisons of means of each treatment were made with the Duncan's Multiple Range Test (Costat Software, 1990).

3 Results

3.1 Effect of low temperature

The hatching rate of eggs reached 65.0% after 7 days of storage at 6.0°C. However, no egg hatching was observed after 15, 30, 45 and 60 days of storage. (table 1).

Data in table 1 indicated that there was 50, 85, 90 and 100% survival from the first, second, third and fourth instar larvae after storage for 7 days. However, after 15 days, the survival percentage of the four larval instars declined markedly to 0, 10, 15 and 15, respectively. No larvae survived after 30 to 60 days of storage.

Eighty five per cent of pupae were viable and emerged after 7 days of storage. Although, 65.0 and 25.0% of adults emerged from pupae which had been stored for 15 and 30 days, no adults were emerged after 45 and 60 days of storage.

From table 1, it can be seen that the survival of adults stored directly after emergence without feeding ranged from 25% (after 7 days storage) to 10% (after 30 days storage), with no adults surviving after 45 and 60 days of storage. In the case of adults that were stored at 5 days after emergence with prior feeding by aphids, the survival varied from 100% (after 7 days storage) to 15% (after 60 days storage). For the adults that were stored at 10 days after of emergence with previous feeding on aphids, the survival rates were 100, 75, 60 and 50% after 7, 15, 30 and 45 days of storage, respectively. However, the survival rate after 60 days storage declined sharply to 35.0% (table 1).

3.2 Effect of various storage periods on adult longevity, fecundity and consumption rate

3.2.1 Group 1 (stored directly after emergence without feeding)

The data in table 2 showed that the pre-oviposition period of *C. undecimpunctata* female resulting from storage conditions varied from 5.2 ± 0.63 (control) to 7.0 ± 0.0 (15 days storage). There was no significant difference in the pre-oviposition period of females that had been stored at 6.0°C for 7, 15 and the control (unstored). The oviposition period ranged from 37.9 ± 1.91 days (control) to 23.5 ± 0.71 days (15 days of storage). There was significant impact on the oviposition period of females that had been stored for 7 and 15 days. The post-oviposition period of females that were stored for 7 or 15 days at 6.0°C did not differ significantly. Female longevity varied from 53.5 ± 3.47 (control) to 40.0 ± 1.41 days (15 days of storage), these differences being significant. The results of oviposition and consumption rate of females differed significantly up to 15 days of storage (table 2).

The longevity of males differed significantly between the controls and males that had been stored for 7, 15 and 30 days. Longevity varied from 47.9 ± 3.07 (control) to 29.0 ± 0.0 days (30 days of storage). With respect to the consumption rate, there were significant differences between controls and males that had been stored at 6.0°C for 7 to 30 days. The average number of aphids consumed per male ranged from 2667.7 ± 55.17 (control) to 1247.0 ± 0.0 (30 days of storage).

3.2.2 Group 2 (stored 5 days after emergence with continous feeding)

From the results in table 3, no significant differences were noted in pre-oviposition and post-oviposition periods between adult females that were stored for 7–60 days and controls. However, the oviposition period was significantly shorter after 60 and 45 days of storage (29.5 ± 0.71 and 30.2 ± 2.71 days, respectively) compared with 30, 15 or 7 days of storage and control

Table 2. *Effect of low temperature (6°C) and storage periods on the longevity, fecundity and consumption rate of given number from* C. undecimpunctata *adults stored after emergence directly without feeding*

Storage periods (days)	Sex	No.	Longevity (Mean[1] ± SD) (in days) Pre-oviposition	Oviposition	Post-oviposition	Total longevity	No. of eggs/female Mean ± SD	No. of aphids consumed/adult Mean ± SD
7	Male	2	–	–	–	35.0 ± 1.41 B	–	1489.0 ± 9.10 B
	Female	3	6.3 ± 0.58 a	26.7 ± 1.53 b	9.3 ± 0.58 a	42.3 ± 2.52 b	804.66 ± 13.05 b	2415.0 ± 10.0 b
15	Male	1	–	–	–	31.0 ± 0.0 C	–	1426.0 ± 0.0 C
	Female	2	7.0 ± 0.0 a	23.5 ± 0.71 c	9.5 ± 0.71 a	40.0 ± 1.41 b	736.5 ± 4.95 c	2367.5 ± 24.75 c
30	Male	1	–	–	–	29.0 ± 0.0 C	–	1247.0 ± 0.0 D
	Female	0	–	–	–	–	–	–
45	Male	0	–	–	–	–	–	–
	Female	0	–	–	–	–	–	–
60	Male	0	–	–	–	–	–	–
	Female	0	–	–	–	–	–	–
Control (unstored)	Male	10	–	–	–	47.9 ± 3.07 A	–	2667.7 ± 55.17 A
	Female	10	5.2 ± 0.63 a	37.9 ± 1.91 a	10.4 ± 1.57 a	53.5 ± 3.47 a	1020.1 ± 39.14 a	3894.4 ± 58.20 a

[1] Means followed by the same small or capital letter in a column are not significantly differences at the 1% level of probability (Duncan's multiple range test).

(unstored) (31.8 ± 0.88, 33.6 ± 1.58, 36.2 ± 1.48 and 37.9 ± 1.91 days, respectively). The results of fecundity are presented in table 3. The average number of eggs laid per female varied from 881.0 ± 20.85 (45 days storage) to 1020.1 ± 39.14 (control).

The data in table 3 indicate that there was significant variation among storage periods and control (unstored) in the longevity and consumption rate of males. The longevity period resulting from storage of adult male *C. undecimpunctata* varied from 47.7 ± 4.02 (7 days of storage) to 36.0 ± 0.0 days (60 days of storage). The average number of aphids consumed per male differed from 2667.7 ± 55.17 (control) to 1548.0 ± 0.0 (60 days of storage).

3.2.3 Group 3 (stored 10 days after emergence with continous feeding)

The results presented in table 4 show that there was significant impact in oviposition and total longevity periods when females were stored at 6.0°C for different periods. The oviposition period was shorter after 60 days of storage. However, there was no significant variation between pre-oviposition and post-oviposition periods of females for different storage periods (table 4). With regard to the fecundity and consumption rate, there was significant impact among the storage periods and controls (unstored). The oviposition of female resulting from storage conditions varied from an average of 1020.1 ± 39.14 and 1002.1 ± 26.9 (control and 7 days of storage) to 883.5 ± 14.48 eggs (60 days of storage). In respect of consumption rate, the average number of aphids consumed by a female differed between 3686.9 ± 48.74 (15 days of storage) and 2910.3 ± 24.89 (60 days of storage).

The data in table 4 shows that the longevity of males resulting from storage conditions ranged from 47.8 ± 3.82 (7 days of storage) to 42.3 ± 1.53 days (60 days of storage) with significant variation. The average number of aphids consumed per male averaged 2354.5 ± 63.30 when males were stored for 30 days at 6.0°C and 1832.7 ± 20.53 for those stored for 60 days.

3.3 Effect of prior feeding of adults before storage

3.3.1 Longevity

Figure 1 illustrates the effect on female longevity of feeding adults after eclosion from pupae for different periods of storage. It can be seen that the longevity differed significantly due to the continous feeding with aphids before storage. However, there was no significant impact between 5 days and 10 days of feeding for adults that were stored for 7, 45 and 60 days, although there were significant differences for those stored for 15 and 30 days. There were also significant variations between 5 and 10 days continous feeding and adults that were stored directly after emergence without feeding.

Concerning male longevity, there were significant differences between males that were stored after emergence without feeding and males stored after 5 or 10 days of prior feeding. There were significant variations between males stored after 5 and 10 days of continous

Table 3. *Effect of low temperature (6°C) and storage periods on the longevity, fecundity and consumption rate of given number of* C. undecimpunctata *adults stored after five days from emergence with prior feeding*

Storage periods (days)	Sex	No.	Longevity (Mean[1] ± SD) (in days)				No. of eggs/female Mean ± SD	No. of aphids consumed/adult Mean ± SD
			Pre-oviposition	Oviposition	Post-oviposition	Total longevity		
7	Male	10	–	–	–	47.7 ± 4.02 A	–	2123.8 ± 39.53 B
	Female	10	5.8 ± 0.79 a	36.2 ± 1.48 a	11.6 ± 0.84 a	53.6 ± 1.35 a	994.0 ± 25.56 b	3549.0 ± 84.38 b
15	Male	7	–	–	–	43.7 ± 1.98 B	–	2075.0 ± 36.70 C
	Female	9	6.2 ± 0.67 a	33.6 ± 1.58 b	11.2 ± 0.83 a	51.1 ± 2.37 ab	909.2 ± 28.82 c	3329.6 ± 48.08 c
30	Male	6	–	–	–	40.6 ± 3.88 C	–	1996.8 ± 26.42 D
	Female	8	6.8 ± 0.46 a	31.8 ± 0.88 bc	10.3 ± 1.39 a	48.8 ± 1.91 bc	895.0 ± 29.05 d	3223.8 ± 40.88 d
45	Male	4	–	–	–	39.5 ± 1.73 C	–	1841.5 ± 20.44 E
	Female	6	7.2 ± 0.75 a	30.2 ± 2.71 c	10.3 ± 1.37 a	47.7 ± 3.44 c	881.0 ± 20.85 f	3013.2 ± 37.93 e
60	Male	1	–	–	–	36.0 ± 0.0 C	–	1548.0 ± 0.0 F
	Female	2	6.5 ± 0.71 a	29.5 ± 0.71 c	10.5 ± 0.71 a	46.5 ± 2.12 c	885.0 ± 7.07 e	2770.0 ± 14.14 f
Control (unstored)	Male	10	–	–	–	47.9 ± 3.07 A	–	2667.7 ± 55.17 A
	Female	10	5.2 ± 0.63 a	37.9 ± 1.91 a	10.4 ± 1.57 a	53.5 ± 3.47 a	1020.1 ± 39.14 a	3894.4 ± 58.20 a

[1] Means followed by the same small or capital letter in a column are not significantly differences at the 1% level of probability (Duncan's multiple range test).

feeding, after 30 and 60 days of storage, but there were no significant differences for males that were fed on aphids for 5 or 10 days before storage for 7, 15 or 45 days (fig. 2).

3.3.2 Fecundity

Data in fig. 3 indicate that there were significant differences in fecundity among females that received continous feeding for 5 or 10 days before storage for 7, 30 and 45 days, but no significant impact was noted for those stored for 15 and 60 days.

3.3.3 Consumption rate

Consumption rate of adult female in relation to storage conditions varied from 3686.9 ± 48.74 aphids/female (with prior feeding for 10 days and stored for 7 days) to 2367.0 ± 24.75 aphids/female (females stored directly after emergence) (fig. 4). Statistically, there were significant variations between females that were stored directly after emergence, and after 5 and 10 days of continous feeding. The same trend was also recorded for adult males as shown in fig. 5.

4 Discussion

The effect of low temperatures on the biological and physiological characters of many biological control agents have been studied previously (Borodkin, 1973; Hamalainen, 1977; Hamalainen and Markkula, 1977; Hofsvang and Hagvar, 1977; Deng, 1982; Tauber et al., 1993; McEwen, 1996 and Abdel-Salam et al., 1997).

Storage of coocinellid predators may be helpful in achieving successful biological control. Seasonal synchrony with the target pest species is a major adaptation of coccinellid predators (Tauber and Tauber, 1978). Storage of predators at low temperature is a simpler method for keeping large numbers of the predators dormant for short- or long-term and taking them to suitable conditions for reproduction and to suppress the insect pests when required (Hodek et al., 1973; Hamalainen, 1977).

This study is the first report in Egypt of the effect of low temperature for several storage periods on *C. undecimpunctata*. Results indicate that the eggs of this coccinellid predator can be stored at 6°C for 7 days with little loss of viability; however, after 15–60 days of storage, viability declined sharply to 0%. This finding are in agreement with those obtained by Shands and Simpson (1972) who found that *C. septempunctata* eggs can be stored at 10°C for 1–6 days before introducing them to potato fields; however, the hatching percentage was not precisely defined. Frazer et al. (1974) also mentioned that at 10°C, eggs of lady beetle may be safely stored for 10 days. Hamalainen and Markkula (1977) reported that eggs of *C. septempunctata* could be stored for 1 week and *A. bipunctata* for 2 weeks at 10°C without any marked reduction in hatching percentage, but at 6.5 and 3°C, only a few hatched after such storage. Similarly, Osman and Selman (1993) held eggs of *Chrysoperla carnea* Steph. at 4 and 8°C for

Table 4. *Effect of low temperature (6°C) and storage periods on the longevity, fecundity and consumption rate of given number of* C. undecimpunctata *adults stored after 10 days from emergence with prior feeding*

Storage periods (days)	Sex	No.	Longevity (Mean[1] ± SD) (in days)				No. of eggs/female Mean ± SD	No. of aphids consumed/adult Mean ± SD
			Pre-oviposition	Oviposition	Post-oviposition	Total longevity		
7	Male	10	–	–	–	47.8 ± 3.82 A	–	2312.6 ± 52.13 C
	Female	10	5.9 ± 0.57 a	36.4 ± 1.58 ab	11.5 ± 1.27 a	53.8 ± 1.99 a	1002.1 ± 26.9 b	3686.9 ± 48.74 b
15	Male	7	–	–	–	45.5 ± 1.69 AB	–	2354.5 ± 63.30 B
	Female	8	6.8 ± 0.89 a	35.4 ± 2.50 ab	12.4 ± 0.74 a	54.5 ± 2.78 a	909.8 ± 32.38 c	3787.6 ± 33.61 c
30	Male	6	–	–	–	44.2 ± 2.48 bc	–	2227.2 ± 27.42 D
	Female	6	6.3 ± 0.52 a	34.0 ± 2.45 bc	12.3 ± 0.52 a	52.7 ± 1.97 a	899.3 ± 19.54 d	3530.5 ± 44.14 d
45	Male	4	–	–	–	41.8 ± 2.36 C	–	2011.8 ± 25.90 E
	Female	6	7.0 ± 0.89 a	31.8 ± 1.33 cd	11.2 ± 0.98 a	50.0 ± 1.26 b	891.2 ± 22.69 e	3214.8 ± 51.15 e
60	Male	3	–	–	–	42.3 ± 1.53 C	–	1832.7 ± 20.53 F
	Female	4	7.0 ± 0.82 a	31.0 ± 1.41 d	10.5 ± 1.0 a	48.5 ± 2.38 b	883.5 ± 14.48 f	2910.3 ± 24.89 f
Control (unstored)	Male	10	–	–	–	47.9 ± 3.07 A	–	2667.7 ± 55.17 A
	Female	10	5.2 ± 0.63 a	37.9 ± 1.91 a	10.4 ± 1.57 a	53.5 ± 3.47 a	1020.1 ± 39.14 a	3894.4 ± 58.20 a

[1] Means followed by the same small or capital letter in a column are not significantly differences at the 1% level of probability (Duncan's multiple range test).

1–20 days. They reported that the eggs had little decrease in hatchability.

The survival rate of third and fourth instar larvae was also high for 7 days of storage. At 6.0°C the third and fourth instar could be stored for 7 days, but after 15 to 60 days of storage, the survival rate declined. These instars may be suitable for shipping to distributors who need the larval stage for controlling aphids, soft-bodied insects and others. ARCHER et al. (1973) reported that higher mortality at colder temperature indicates a negative effect on metamorphosis and survival.

From the data obtained in table 1, it can be concluded that the pupal stage can be stored for 15 days with only a little reduction in percentage of emergence. QUEZADA and DEBACH (1973) reported that the emergence of *R. cardinalis* pupae was 100 and 50% after 35 and 48 days at 55°F (12.5°C).

The present results indicate that the survival of adults stored after feeding with aphids for 5 or 10 days was high for storage up to 45 days. The survival declined to 35% after 60 days of storage. Similar results were achieved by QUEZADA and DEBACH (1973) who noted that the survival of *R. cardinalis* adults was 100 and 54% at 55°F (12.5°C) for 45 and 95 days. HAMALAINEN (1977) also mentioned that the mortality rate of *C. septempunctata* adults was high after only 30–60 days of storage at 6.0°C. ABDEL-SALAM et al. (1997) reported that the survival percentage of *H. axyridis* adults was 100% at 4, 8 and 12°C for 30 days, but after 60 days of cold storage, the survival decreased to 60, 40 and 0%, respectively, for the same temperatures. Generally, when the storage period increased, the hatching, survival and emergence percentages were decreased.

Storage possibility of eggs, larvae and pupae for short-term (7 days) and adults for long-term (45 days) would be suitable for synchronization with certain insect pests in order to use this coccinellid predator in biological control programmes. It would appear from the results of this study that the adult stage with prior feeding before storage is the tolerant stage for long-term storage because the diapause stage mostly occurs in the adult stage of concinellid predators (HODEK et al., 1973).

Additionally, there was no significant difference in pre-ovipostion and post-oviposition after various storage periods, but there was significant impact on oviposition period, fecundity and consumption rate of females and longevity and consumption rate of males. ABDEL-SALAM et al. (1997) noted that storage periods did not significantly affect oviposition at 4, 8 and 12°C.

The results also indicate the significant effects of prior feeding of the adult stage before storage on survival, longevity, fecundity and consumption rate of females and longevity and consumption rate of males. Similar results were reported by DENG (1982) who concluded that when *H. axyridis* adults were fed on an artificial diet for 10–30 days and stored at 5.0°C for 100–120 days, 90.9 to 96.3% of the adults survived compared with 65.3% of those stored at the same temperature without prior feeding.

In conclusion, from these results it is clear that the

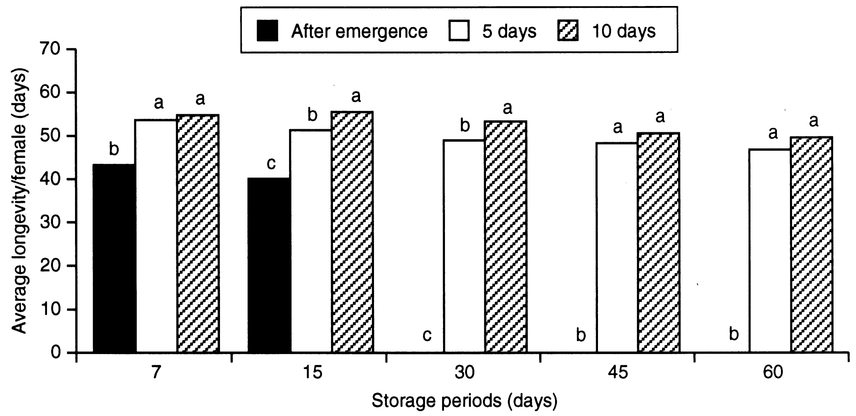

Fig. 1. *Effect of low temperature and storage periods on the longevity of females stored immediately after emergence, or 5 and 10 days after emergence. Same letters at tops of columns of same storage period indicate nonsignificant differences at the 1% level of probability (Duncan's multiple range test)*

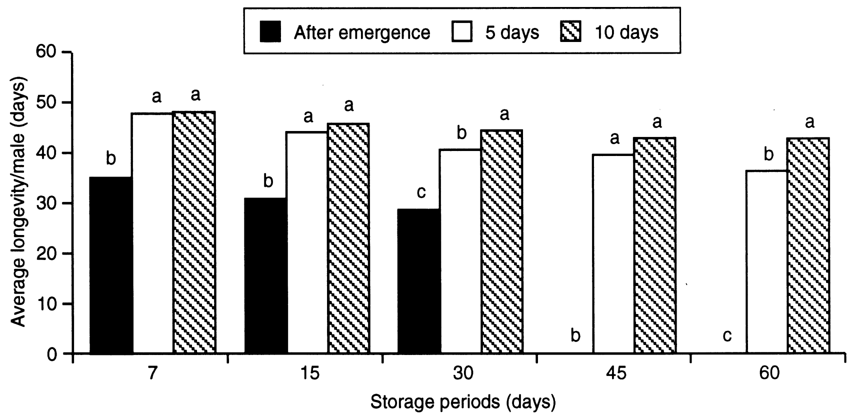

Fig. 2. *Effect of low temperature and storage periods on the longevity of males stored immediately after emergence, or 5 and 10 days after emergence. Same letters at tops of columns of same storage period indicate nonsignificant differences at the 1% level of probability (Duncan's multiple range test)*

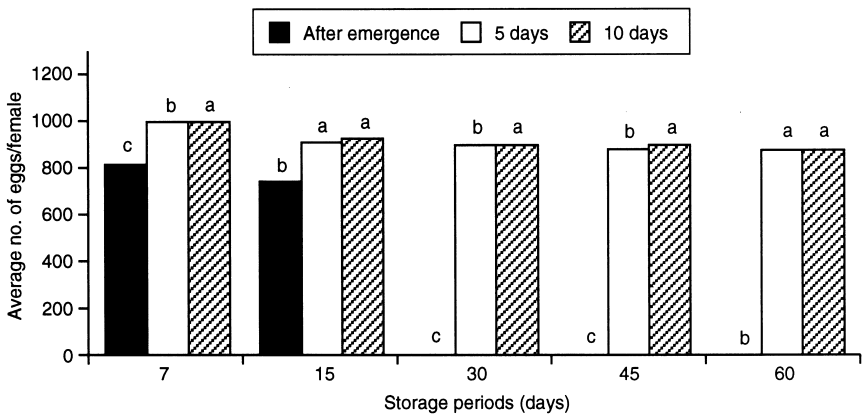

Fig. 3. *Effect of low temperature and storage periods on the fecundity of females stored immediately after emergence, or 5 and 10 days after emergence. Same letters at tops of columns of same storage period indicate nonsignificant differences at the 1% level of probability (Duncan's multiple range test)*

immature stages can be stored for 7 days with only a little loss of viability, survival or emergence, whereas the adult stage with prior feeding before storage is the most suitable for long-term storage. Integration of cold storage of coccinellid predator with mass rearing could help achieve the purpose of this study.

However, complete evaluation when stored *C. undecimpunctata* stages were released in open field or greenhouses as a biological control candidate, its efficacy against certain insect pests (e.g. aphids and soft-bodied insects), and additional information on longevity, fecundity and consumption rate under open field and greenhouse conditions need to be addressed in the future experiments.

Acknowledgements

We would like to thank Drs A. M. Abou El-Naga and M. A. El-Adl, Economic Entomol. Department, Faculty of Agriculture, Mansoura University, El-Mansoura, Egypt, for their critical reviews of the manuscript. Helpful, comments on the manuscript were kindly provided by Dr A. A. Ghanim at the same department.

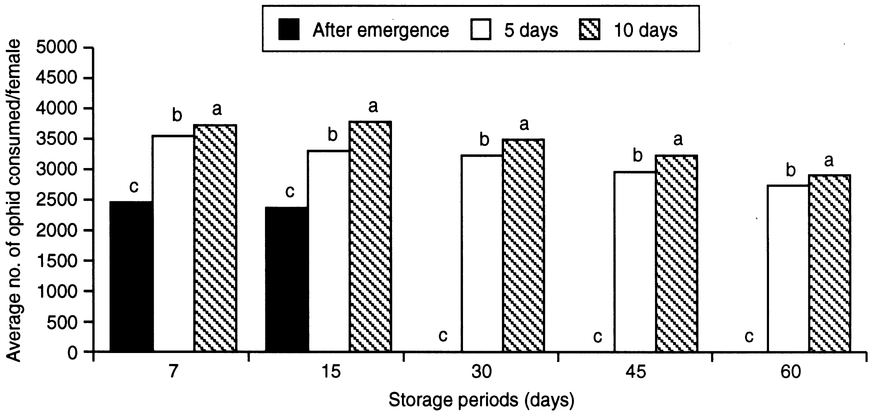

Fig. 4. Effect of low temperature and storage periods on consumption rate of females stored immediately after emergence, or 5 and 10 days after emergence. Same letters at tops of columns of same storage period indicate nonsignificant differences at the 1% level of probability (Duncan's multiple range test)

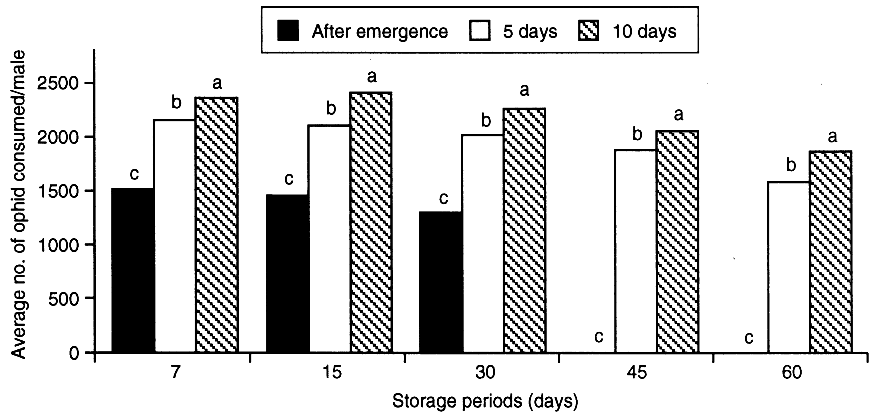

Fig. 5. Effect of low temperature and storage periods on consumption rate of males stored immediately after emergence, or 5 and 10 days after emergence. Same letters at tops of columns of same storage period indicate nonsignificant differences at the 1% level of probability (Duncan's multiple range test)

References

ABDEL-SALAM, A. H., 1995:The biotic factors: evaluation of their performance under natural conditions in cotton plantations. PhD Thesis, Faculty of Agric., Mansoura University

ABDEL-SALAM, A. H.; ELLINGTON, J. J.; EL-ADL, M. A.; ABOU EL-NAGA, A. M.; GHANIM, A. A., 1997: Effect of cold storage on survival, longevity and fecundity of *Harmonia axyridis* adults. Proceedings of the 1st Nat. Conf., Mansoura University September 1997, Vol. I. Mansoura, Egypt: Fac. Agric., Mansoura Univ., 58–72.

ALI, M. A.; EL-KOULY, A. S.; IBRAHIM, I. L.; TAMER, F. H., 1989: Effect of certain pesticides application on the survival rate and population density of *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae). J. Agric. Sci. Mansoura Univ. **14,** 779–783.

ARCHER, T. L.; MURRAY, C. L.; ERIKENBARY, R. D.; STARKS, K. J.; MORRISON, R. D., 1973: Cold storage of *Lysiphlebus testaceipes* mummies. Environ. Entomol. **2,** 1104–1108.

BORODKIN, I., 1973: Naturschutz und biologischer Pflanzenschutz. Intern. Z. Landw. **4,** 394–397.

COSTAT SOFTWARE, 1990: Microcomputer Program Analysis, Version 4.20. Berkely, CA: CoHort Software.

DARWISH, Y. A.; ALI, A. M., 1991: Field population trends of cereal aphids and their natural enemies on corn plants in Upper Egypt. Assiut J. Agric. Sci. **22,** 33–42.

DENG, D. A., 1982: Experiments on feeding with artificial diets and cold storage of *Harmonia axyridis* Pallas. Insect Knowledge **19,** 11–12.

EL-GHAREEB, A. M., 1992: Target site sensitivity and detoxification processes in relation to insecticide potency and selective toxicity in cotton leafworm and ladybird. Assiut J. Agric. Sci. **23,** 113–128.

EL-HENEIDY, A. H.; ATTIA, A. A., 1991: Evaluation of the role of parasitoids and predators associated with aphids in wheat fields. Egypt. Bull. Ent. Soc. Egypt., Econ. Ser. **17,** 137–147.

EL-HENEIDY, A. H.; ABBAS, M. S. T.; EL-DAKROURY, M. S. I., 1979: Seasonal abundance of certain predators in untreated Egyptian clover and cotton fields in Fayoum Governorate. Egypt. Bull. Ent. Soc. Egypt. **62,** 89–95.

EL-MAGHRABY, M. M. A.; EL-TANTAWY, M. A.; GOMAA, E. A. A.; NADA, M., 1994: Effect of pesticidal application during the early and late cotton season on the abundance of certain predators associated with cotton plants. Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz. **67,** 60–62.

ERAKY, S. A.; NASSER, M. A. K., 1993: Effect of constant temperatures on the development and predation prey efficiency of the ladybird beetle, *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae). Assiut J. Agric. Sci. **24,** 223–231.

FAYAD, Y. H.; IBRAHIM, A. A., 1988: Impact of successive insecticidal applications at different interval period on the number of predator in cotton fields. Bull. Ent. Soc. Egypt. Econ. Ser. **15,** 47–58.

FRAZER, B. D.; RAWORTH, D.; BRYAN, A., 1974: Rearing natural enemies of aphids for ecological studies. J. Ent. Soc. Brit. Columbia **71,** 35–37.

GHANIM, A. A.; EL-ADL, M. A., 1987a: The role of *Coccinella undecimpunctata* L. in suppressing the population level of *Schizaphis graminum* (Rond) and increase the yield in wheat plantation at Dakahlia Governorate, Egypt. J. Agric. Sci. Mansoura Univ. **12,** 965–974.

GHANIM, A. A.; EL-ADL, M. A., 1987b: The feeding capacity and duration of the larval instars of three ladybird beetles fed on different aphid species under natural weather conditions at Mansoura, Egypt. J. Agric. Sci. Mansoura Univ. **12,** 981–987.

GHANIM, A. A.; EL-ADL, M. A., 1987c: Evaluation of predation activity and fecundity of the coccinellids, *Cydonia (Chilomenes) vicina isis* Cr., *Cydonia (Chilomenes) vicina nilotica* Muls. & *Coccinella undecimpunctata* L. in Mansoura region, Egypt. J. Agric. Sci. Mansoura Univ. **12,** 993–1000.

HAFEZ, M.; FAYAD, Y. H.; SARHAN, A. A., 1977: Preliminary indication of effect of Nuvacron U.L.V. on abundance of predators in cotton fields in Egypt. Agric. Res. Review **55,** 111–116.

HAMALAINEN, M., 1977: Storing dormant *Coccinella septempunctata* and *Adalia bipunctata* (Col., Coccinellidae) adults in the laboratory. Ann. Agric. Fenn. **16,** 184–187.

HAMALAINEN, M.; MARKKULA, M., 1977: Cool storage of *Coccinella septempunctata* and *Adalia bipunctata* (Col., Coccinellidae) eggs for use in the biological control in greenhouses. Ann. Agric. Fenn. **16,** 132–136.

HAMED, A. R.; HASSANEIN, F. A., 1984: Assessment of the role of *Coccinella undecimpunctata* L. (Col., Coccinellidae) as a biological control agent against *Spodoptera littoralis* Boisd. J. Appl. Ent. **97,** 520–528.

HAMED, A. R.; HASSANEIN, F. A.; ABBAS, M. S. T., 1979: Effects of certain pesticides on abundance of predators in cotton fields. In: Proc. 1st Conf. Agric. Research Center, Cairo, Egypt, Abstract Vol. II. Cairo, Egypt: Agric. Research Center, Ministry of Agric.

HAMED, A. R.; HASSANEIN, F. A.; ABBAS, M. S. T., 1983: On the abundance of certain predators in cotton fields. In: Proc. 5th Arab Conf., Tanta University, September 1983, Vol. II. Kafr El-Sheikh, Egypt: Fac. Agric., Karf El-Sheikh, Tanta Univ.

HASSANEIN, F. A.; HAMED, A. R., 1983: Parasites of *Coccinella undecimpunctata* and *Scymnus syriacus* in Egypt. In: Proc. 5th Arab Conf., Tanta University, September 1983, Vol. II. Kafr El-Sheikh, Egypt: Fac. Agric., Kafr El-Sheikh, Tanta Univ.

HODEK, I.; RUZICKA, Z.; SEHNAL, F., 1973: Termination of diapause by juvenoids in two species of ladybirds (Coccinellidae). Experientia **29,** 1146–1147.

HOFSVANG, T.; HAGVAR, E. B., 1977: Cold storage tolerance and supercooling points of mummies of *Ephedrus cerasicola* Stary and *Aphidius colemani* Vierech (Hym., Aphidiidae). Norw. J. Entomol. **24,** 1–6.

IBRAHIM, M. M., 1955: Studies of *Coccinella undecimpunctata* L (Coleoptera: Coccinellidae). II. Biology and life history. Bull. Ent. Soc. Egypt **39,** 395–423.

KAYAPINAR, A.; KORNOSOR, S., 1993: Investigation of the effect of the predatory insects on larval stages of *Ostrinia nubilalis* Hübner (Lep., Pyralidae). Turkiye Entomoloji Dergisi **17,** 69–76.

MCEWEN, P. K., 1996: Viability of green lacewing, *Chrysoperla carnea* Steph. (Neuropt., Chrysopidae) eggs stored in potential spray media, and subsequent effects on survival of first instar larvae. J. Appl. Ent. **120,** 171–173.

OSMAN, M. Z.; SELMAN, B. J., 1993: Storage of *Chrysoperla carnea* Steph. (Neuroptera: Chrysopidae) eggs and pupae. J. Appl. Entomol. **115,** 420–424.

QUEZADA, J. R.; DEBACH, P., 1973: Bioecological and population studies of the cottony-cushion scale, *Icerya purchasi* Mask. & its natural enemies, *Rodalia cardinalis* Mul. & *Cryptochaetum iceryae* Will. in Southern California. Hilgardia **41,** 631–688.

SHANDS, W. A.; SIMPSON, G. W., 1972: Insect predators for controlling aphids on potatoes. 4. Spatial distribution of introduced eggs of two species of predators in small fields. J. Econ. Entomol. **65,** 805–809.

TAUBER, M. J.; TAUBER, C. A., 1978: Evolution of phenological strategies in insects: a comparative approach with eco-physiological and genetic considerations. In: Evolution of Insect Migration and Diapause. Ed. by DINGLE, H. New York: Springer, 53–71.

TAUBER, M. J.; TAUBER, C. A.; GARDESCU, S., 1993: Prolonged storage of *Chrysoperla carnea* Steph. (Neuroptera: Chrysopidae). Environ. Entomol. **22,** 843–848.

Authors' address: A. H. ABDEL-SALAM (corresponding author), N. F. ABDEL-BAKY, Economic Entomology Department, Faculty of Agriculture, Mansoura University, El-Mansoura-35516, Egypt